Distinct Hydrological Signatures in Observed Historical Temperature Fields

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Abstract

In an atmospheric general circulation model (AGCM), the physical bounds on soil moisture content and the nonlinear relationship between soil moisture and evaporation lead to distinct geographical patterns in key surface energy and water balance variables. In particular, simple hydrological considerations suggest -- and extensive AGCM simulations confirm -- that the variance and skew of seasonally-averaged air temperature on the planet should be maximized in specific, and different, regions: a variance maximum should appear on the dry side of the soil moisture variance maximum, and a positive skew maximum should appear on the wet side of the temperature variance maximum. We test these ideas with multi-decade observational temperature data from the Global Historical Climatology Network (GHCN). In the United States, where sufficient data exist, the predicted patterns in the seasonal temperature moments show up where expected. This agreement is either a coincidence, or the hydrological considerations do indeed control the patterns of seasonal temperature variance and skew in nature.

Popular Summary

The literature is filled with modeling studies showing how soil moisture variations affect rainfall, air temperature, and other meteorological quantities. Much more difficult, and often impossible, is demonstrating with observational data that this land-atmosphere feedback exists in the real world. The difficulty has two sources: the lack of comprehensive data spanning long time periods, and the dominance of the other direction of causality, i.e., the fact that observed correlations between soil moisture and meteorological variables are more likely caused by the latter affecting the former.

Still, if care is taken in the analysis of observational data, distinct signatures of land-atmosphere feedback can be isolated. This paper isolates such signatures in the multi-decade air temperature record covering the United States. The positions of the second and third moments (the variance and skew) of seasonal air temperature variations appear where expected according to basic hydrological considerations. Unless this is pure coincidence, land-atmosphere feedback does impose a strong control on seasonal air temperature variations – we have found the desired evidence of feedback.